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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Horticultural Crops Research Branch
Beltsville, Maryland

GROWING CROPS WITHOUT SOIL

Growing plants in water or sand without the use of soil has interested students of plant nutrition and other plantmen for more than a century.

In the decade just prior to the outbreak of the second World War popular interest in soilless culture increased greatly. This interest was aroused by the results of research work at the Agricultural Experiment Stations of California, Indiana, New Jersey, and Ohio. The first trials were made in greenhouses with ornamental crops or with vegetables such as tomatoes and cucumbers in the winter. Here the new method in large degrees did away with the need for obtaining and handling large quantities of soil and manure annually and for water, weeding, fertilizing, and soil sterilizing.

During World War II, the United States Army Air Forces used the soilless culture method for the production of vegetables at certain isolated air bases. At these locations vegetables could not be grown in the available soil or with the natural water supply.

At the present time three general methods of crop production with nutrient solutions, collectively termed "nutriculture", are in use. These are (1) sand culture; (2) water culture, sometimes called hydroponics; and (3) subirrigation culture, also called gravel or cinder culture.

In sand culture the soil in beds or benches is replaced with fine sand, which is watered with a nutrient solution applied to the surface of the sand. Workers at the New Jersey Agricultural Experiment Station have developed the sand culture method. This method is simple and with proper management is capable of producing good crops. It is useful for experimental studies but is not well suited for large-scale production of crops as it is wasteful of water and nutrients, since surpluses applied in watering drain away.

The water-culture method has received much more attention but frequently is not well understood. The plants are grown with their roots suspended in a nutrient solution contained in shallow tanks. They are supported above the water by wire netting or hardware cloth, which is covered with straw, wood shavings, or rice hulls in order to exclude light from the solution and maintain a high humidity around the upper roots. The solution must be aerated in order to supply sufficient oxygen to the roots.



This is done by circulating the solution with a pump that mixes air with it or by bubbling air into the solution through perforated pipes. The need for aerating the solution and the difficulty of supporting the plants are disadvantages of the method. Control of the composition of the nutrient solution is also somewhat more exacting than in other methods of soilless culture. Workers at the California Agricultural Experiment Station have contributed most toward developing this method.

In the subirrigation method of culture, watertight beds or benches are filled with gravel or other suitable inert material which is irrigated from the bottom of the bed. This method overcomes some of the limitations of the sand-culture and water-culture systems. It was developed in 1934 at the New Jersey and Indiana Agricultural Experiment Stations. Subirrigation is accomplished by pumping the nutrient solution from the storage tank or cistern into the bench, the bottom of which slopes slightly from the sides to the middle and also lengthwise. Inverted half-round clay tiles or boards nailed together to form an inverted V are placed end to end lengthwise along the middle of the bench and serve as a channel for the solution. When the solution has nearly filled the bench the pump is stopped either manually or by an electric time switch and the solution drains back to the tank by gravity. This type of installation, known as the direct-feed system, is useful in greenhouses, propagation units, or other small systems. In the newer benches built for subirrigation a solution channel is formed by making a longitudinal depression along the lowest part of the floor. The channel thus formed is covered with bricks or slabs of concrete provided with drainage holes at the sides. To facilitate rapid drainage these holes are covered with coarse gravel.

For larger installations it is more economical to employ the gravity-feed system. The beds or benches are divided into 3 or 4 sections, each on a higher elevation and slightly longer than the one following it. Two solution tanks are used in this system. The larger one is located at the lower end of the beds and is below ground. It is connected by means of a flume with a somewhat smaller tank about the level of the beds. The second tank should have a capacity approximating one-half the volume of the first sections of all the beds. This tank is filled from the larger or sump tank before an irrigation is made. The nutrient solution flows into the first bed sections by gravity and then successively through the other sections, finally emptying into the sump tank. By this means only the solution for irrigating the first sections of the beds has to be pumped, gravity flow irrigating the rest of the sections. After one or more irrigations have been made the solution in the sump tank is analyzed, reinforced with the necessary nutrients, made to volume, and pumped into the elevated tank in preparation for the next irrigation. This system has been used by the United States Army in operation of soilless culture gardens at Ascension Island, Atkinson Field in British Guiana, and Iwo Jima and in Japan.

A modification of tier construction known as the open-flume system has been developed in Florida. All of the solution is carried to and from the beds by means of a flume so that no piping or valves are necessary except at the pump. The nutrient solution is stored in an above-ground tank, with a small sump tank for the pump, or in a below-ground cistern.

Benches or beds intended for subirrigation are usually built of suitably reinforced concrete. They should always be coated on the inside with nontoxic petroleum asphalt applied hot, as an emulsion, or cut back in a volatile solvent. The asphalt serves to waterproof the beds as well as to protect them from the slightly acidic nutrient solution. It is possible to construct ground beds of asphalt macadam prepared by mixing hot asphalt with sand and molding it into shape while hot. This type of bed was used in the Ascension Island installation.

Prefabricated bituminous surfacing (PBS) consisting of burlap saturated with asphalt has been successfully used for constructing subirrigated beds in the Iwo Jima garden. This material comes in rolls 3 feet wide and has the advantage of being tough, flexible, waterproof, and easily laid. If it becomes generally available PBS should be very satisfactory for waterproofing existing wooden benches for subirrigation.

Several naturally occurring mineral materials, or aggregates, have been used in the soilless culture of a number of plants. Lava cinder was screened and used in the beds on Ascension Island and Iwo Jima. Gravel washed free of sand clay has been widely used in the United States. Sintered shale (Haydite), a commercial product used in making low-density concrete, is porous, is light in weight, and has a higher water-holding capacity than gravel. Calcareous aggregates (coral limestone) have produced satisfactory crops experimentally after being pretreated with phosphate solutions to stabilize the acidity in the solution. Expanded vermiculite, a micaceous silicate used industrially as an insulating material, appears promising as an aggregate in soilless culture tests at the Plant Industry Station. Haydite and vermiculite contain calcium and potassium and tend to absorb phosphates which are available to the plants growing in them. Consequently the acidity and nutrient balance of solutions used on them do not fluctuate as rapidly as when the aggregate is gravel. The particle size of the aggregates should lie between one-sixteenth inch and one-half inch in diameter. The frequency of irrigation is determined in part by the water-retaining capacity of the beds. This in turn depends to a considerable extent upon the particle size and porosity of the aggregate.

The nutrient solution supplies water and oxygen as well as mineral elements to the plant roots. Much effort has been expended in attempts to determine the best combination of nutrients for various plants. While many combinations have been proposed, it is now generally recognized that rather wide limits of solution composition are capable of producing

equally good growth of many plants. Climatic factors such as temperature and sunlight intensity as well as the plant part desired - leaf, root, fruit, or flower - are also determining factors in solution composition for optimum growth. It should be recognized that the total volume of the solution in relation to number of plants, the particle size of the aggregate, and the frequency of irrigation and replenishment of absorbed nutrients, as well as the initial solution composition, are important factors in governing growth. With small installations the nutrient solution can be replaced at frequent intervals with a solution prepared by diluting ready-mixed soluble fertilizer concentrates according to the manufacturer's directions. These materials are generally available at garden supply houses. In larger systems it is more economical to test the solution and to replenish the elements as they are absorbed.

Composition of nutrient solutions and methods of testing for the various elements are published in S.C. 328, "Nutriculture", issued by the Purdue University Agricultural Experiment Station, Lafayette, Indiana, and in Research Bulletin 679, "Gravel Culture", issued by the Ohio Agricultural Experiment Station, Wooster, Ohio. A recently published book, "Soilless Growth of Plants", by C. Ellis and M. W. Swaney, revised and enlarged by Tom Eastwood, contains complete directions for construction and operation of soilless culture gardens. This book is published by the Reinhold Publishing Corp., 330 West 42nd Street, New York 18, N. Y.

It must be emphasized that some technical training and considerable experience are necessary for the efficient management of soilless-culture crop production. Successful use of the method requires the same general knowledge of the various phases of plant production that is necessary for growing plants in soil. The future commercial development of soilless culture in the United States will probably be confined to production of crops relatively high in value per unit, such as certain ornamentals, out-of-season vegetables, or seedlings for transplanting. Under favorable conditions yields may be expected to equal or surpass similar yields in soil, but to date the differences have not been outstanding. Soilless culture is also well adapted for specialized studies in plant nutrition, plant diseases, and plant breeding where growth under exact conditions is desired.

